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Biochemical Evaluation of Enclosed Solar Dried and Salted *Oreochromis niloticus*

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Abstract: An experiment to investigate the effect of enclosed solar drying on the quality of unsalted and salted *O. niloticus* was conducted to assess the extent at which the use of enclosed solar dryers combined with salting at different levels would affect the biochemical composition and keeping quality of *Oreochromis niloticus*. Sensory, biochemical and storage evaluations were carried out on the salted and unsalted fish after drying. The acceptability, appearance, colour, odour, taste and texture of salted and unsalted fish differed significantly ($p<0.05$). The moisture, protein lipid and ash contents differed significantly ($p<0.05$). The mineral composition showed that Sodium, Magnesium, and Calcium and Potassium content differed significantly ($p<0.05$). The storage evaluation showed that the Free Fatty Acid (FFA), Iodine Number (IN) and Total Viable Count (TVC) differed significantly ($p<0.05$).

Key words: Enclosed, solar, salted, sensory, biochemical and storage

INTRODUCTION

Open air sun-drying of fish has many limitations. These include the fact that long periods of sunshine without rain are required, drying rates are low and in areas of high humidity and it is often difficult to dry the fish sufficiently. The quality of open-air dried fish is likely to be low due to slow drying, insect damage and contamination from air-borne dust and it is difficult to obtain a uniform product (Trim and Curran, 1983). Thus, in the search for improved drying techniques using naturally abundant solar energy, the use of enclosed solar drying systems have recently been investigated as an alternative to traditional open-air sun drying. These enclosed systems are called solar dryers.

Solar dryers employ some means of collecting or concentrating solar radiation with the result that elevated temperatures and, in turn, lower relative humidities are achieved for drying. When using solar dryers, the drying rate can be increased, lower moisture contents can be attained and product quality is higher. The dryers are less susceptible to variations in weather, although drying is obviously slower during inclement weather, and they do provide shelter from the rain. The high internal temperatures discourage the entry of pests into the dryer and can be lethal to those that enter (Trim and Curran, 1983).

Many forms of solar dryer for use with agricultural and fisheries products have been developed in Nigeria. However, only a few of these have been developed specifically for fish. Few workers (Olokor *et al*., 1997; Ogali and Eyo, 1998) have reported, respectively on some aspects of biochemical changes in fish dried using tent and box types of solar dryers.

In order to improve the quality of open-air dried fish and to provide information on the nutritive and keeping qualities of solar dried fish, this experiment was conducted to assess the effects of enclosed solar drying in the quality of fresh and differently salted *O. niloticus*.

MATERIALS AND METHODS

Experimental equipment: Three Enclosed Solar Drying Systems (EDS) were used. These were:

- Solar Tent Dryer, Natural Airflow Solar Cabinet Dryer and Forced Airflow Solar Cabinet Dryer.

Solar Tent Dryer (STD): STD is shown in Fig. 1. It was made up of polythene sheet stretched over a wooden framework (1.1 m wide ×1.1 m long ×1.5 m high) with side and top vent of (0.25×0.25 m). A framed wire gauzed rack (1×0.54 m) with a drying area of 0.54 m^2 was suspended at about 60 cm off the ground. Underneath the rack was the heat collector made up of a spread of irregularly shaped granite stones painted black.

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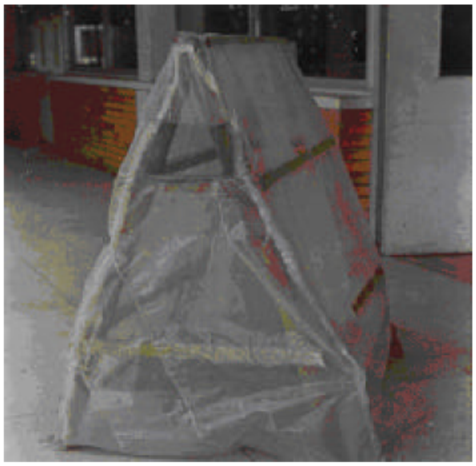

Fig. 1: Std with polythene covering

Fig. 2: Natural airflow cabinet dryer (nacd) used in drying differently salted *O. niloticus*

Natural Airflow Solar Cabinet Dryer (NACD): The NACD is shown in Fig. 2. The drying chamber was painted black both inside and outside. Inside the drying chamber was a framed wire gauzed drying rack (1× 0.54 m) with a drying area of 0.54 m^2 (2). A solar collector made of glass was connected to the drying chamber to produce the drying energy required. Airflow was generated by natural convection through the collector through the drying chamber and moist air leaves the dryer through the upper chimney-like opening.

Forced Airflow Solar Cabinet Dryer (FACD): The FACD is shown in Fig. 3. The drying chamber was painted black both inside and outside. Inside the drying chamber were a framed wire gauzed drying rack (1×0.54 m) with a drying area of 0.54 m^2 and an electric powered two blade fan fixed to the ceiling of the drying chamber to force out the moist air. A solar collector made of glass was connected to the drying chamber to produce the drying energy required. Airflow was generated by natural convection through the collector through the drying chamber and moist air leaves the dryer through the upper chimney-like opening.

Fig. 3: Forced airflow cabinet dryer used in drying differently salted *O. niloticus*

Drying procedure: The solar drying was carried out in each EDS simultaneously. Sixty fresh *O. niloticus* were dried in each EDS used for the experiment. In each EDS the fish were divided into five groups and were salted using (Sodium Chloride-NaCl) at different levels as described by Oyero (2006). First Level-Unsalted treatment (US)-the fish were not salted. Second Level-25% brined treatment (25B)-the fish were immersed in 25% brine for 1 h. The brine was prepared by dissolving 250 g of NaCl in 1 L of water. Third Level-50% brined treatment (50% B)-the fish were immersed in 50% brine for 1 h. The brine was prepared by dissolving 500 g of NaCl in 1 L of water. Fourth Level-75% brined treatment (75B)-the fish were immersed in 75% brine for 1 h. The brine was prepared by dissolving 750 g of NaCl in 1 L of water. Fifth Level-100% Dry Salted treatment (DS)-the fish were rubbed on the surface and inside of the fish. Each level of salting represented a treatment. The drying took place at the Federal University of Technology, Minna. The fish were solar dried for one week.

Experimental evaluation: The sensory evaluation of the dried fish samples were evaluated weekly for 4 weeks by a trained panel of five evaluators. The evaluation was done on Hedonic scale of 5 based on the method of Doe and Olley (1990). The parameters evaluated were taste, colour, odour/smell, texture, appearance and acceptability.

The chemical analyses of proximate composition of the dried samples of *O. niloticus* were carried out using the methods of Association of Analytical Chemists (AOAC, 1990). The parameters analyzed include moisture, crude protein, lipid ash, free fatty acids and mineral composition. The amino acid profile of the dried fish were analyzed using the technicon^{TM} Sequential Multisample Amino Acid Analyzer (TSM), The Total Viable Count (TVC) of the dried were determined using pour plate serial dilution method as described by Brown and Creedy (1970). The Iodine Value was determined using Wijs' method as described by Pearson (1976). The results of the sensory and biochemical evaluations were subjected to one way Analysis of Variance (ANOVA) test and simple factorial method of analysis at 5% probability level. Multiple parameter means comparison of treatments was according to Duncan multiple range tests. All the statistical analyses and graphical presentations of the results were done using (SPSS, 2004).

RESULTS AND DISCUSSION

Sensory evaluation: Figure 4 shows the acceptability of the sensory evaluation of differently salted *O. niloticus* dried using Enclosed Solar Drying Systems (EDS). Acceptability, appearance, colour, odour, taste and texture differed significantly ($p<0.05$). There was a direct relationship between the various parameters (appearance, colour, odour, taste texture and acceptability) of the dried *O. niloticus* products from the three solar dryers (STD, NACD and FACD). Dried samples from STD and NACD showed high levels of acceptability especially STD 25 NACD 25 treatments. None of the dried products in these two enclosed drying systems had a value less than 2.5 on the 5 point hedonic scale of measurement. This indicated that all the dried products from the two systems were widely accepted. However, despite this acceptability the unsalted treatment dried products in the STD and NACD showed the least values. The reverse was the case in the FACD. Only the unsalted treatment dried product in FACD showed a high value of 3.80 on 5 point hedonic scale of measurement. This could be attributed to the fact that the initial rate of drying is governed by heat and mass transfer processes external to the fish relative to the air speed all have direct effect on the drying rate.

Thus in the early stages of drying the rate can be increased by increasing the air speed and temperature and reducing the air relative humidity. However, according to Doe and Olley (1990) there is a limit; if dried too fast a relatively impermeable layer can develop on the surface of the fish (case hardening) and at temperatures above 40^{0}C (depending on the fish species). This could be the situation here as it could be deduced that the forced airflow and the salting levels contributed to fast drying of the products

Table 1 shows the moisture, crude protein, crude lipid and ash contents of differently salted O. *niloticus* dried using Enclosed Solar Drying Systems. Moisture, crude protein, crude lipid and ash contents differed significantly ($p<0.05$). All the treatments had moisture content values below 10%. The moisture contents obtained were lower than those obtained by Trim and Curran (1983). Moisture content was 25% was in the brined products and 25-40% moisture content in dry salted products. This low moisture content indicated that the dried fish products have the tendency to be very stable. From Trim and Curran (1983) results, the brined and dry salted products had a shelf life of approximately 100 days. In all the three drying methods, FACD showed the least of the moisture content when compared at different levels of salting. The moisture content decreased, respectively in the brined dried products, of 25, 50 and 75% brined treatments, according to the level of salting. It was observed that the higher the level of salting of the fish, the lower the moisture content.

As expected, the unsalted dried products had the highest moisture contents in all the three drying methods. This was in line with Horner (1994) that the objective of dehydration is to remove water from the deepest part of the flesh quickly enough to reduce water activity below minimum for microbial growth before significant

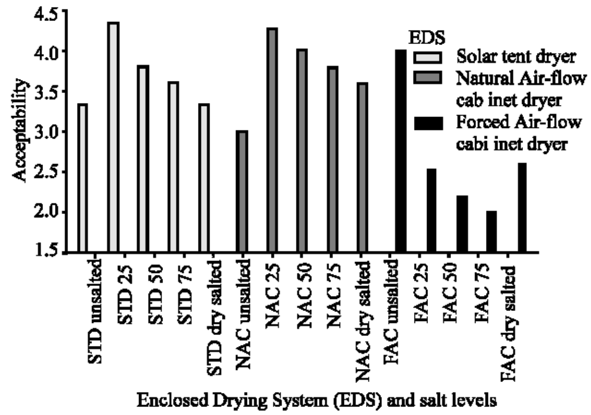

Fig. 4: Mean values of acceptability of *O. niloticus* differently salted and dried using Enclosed Drying Systems (EDS)

Table 1: Mean values of moisture, protein, lipid and ash contents of *O. niloticus* differently salted and dried using Enclosed Drying Systems (EDS)

	Salt levels	Moisture %	Protein %	Lipid %	ASH %
Std	Unsalted	10.01^k	58.86^a	13.40^k	18.09^k
	25% Brined	8.91^e	65.47^i	13.49^e	13.06^g
	50% Brined	8.81^d	64.71^f	14.22^i	12.52^e
	75% Brined	8.65^c	64.20^e	14.03^h	13.10^g
	Dry Salted	9.62^g	63.45^d	12.35^b	13.63^i
Nacd	Unsalted	10.03^k	59.03^b	15.55^m	15.44^j
	25% Brined	9.04^f	65.95^k	12.00^f	12.04^c
	50% Brined	8.53^b	65.03^g	14.42^k	12.03^c
	75% Brined	8.52^b	64.98^g	14.35^j	12.23^d
	Dry Salted	9.73^i	63.50^d	14.35^j	12.63^f
Facd	Unsalted	9.80^j	60.25^c	20.87^n	9.03^a
	25% Brined	8.81^d	65.99^k	13.53^d	11.65^b
	50% Brined	8.45^a	65.55^j	13.95^g	12.06^c
	75% Brined	8.44^a	65.26^h	12.87^c	13.43^h
	Dry Salted	9.68^h	64.15^e	14.49^l	11.65^b

Data in the same column carrying the same superscript do not differ significantly from each other ($p>0.05$)

spoilage takes place, the objective of salting is to ensure that salt penetration is rapid enough to similarly lower the water activity in the deepest parts of the flesh.

There was a strong inverse relationship between the moisture and crude protein contents. The three unsalted dried products had the highest moisture contents. This same trend was observed for all other products. After 4 weeks of storage, all the dried products showed crude protein contents well above 50% with the highest being that of FACD which was 65.99% and was not significant at $p<0.05$ from NACD 25 treatment which was 65.95%. All the dried products had low levels of crude lipid content apart from FACD unsalted treatment which was 20.87% and could be attributed to the nature of *O. niloticus*, which is classified as a lean fish (ILO-WEP, 1982). The reason for the exceptionally high crude protein content in the FACD unsalted treatment could not be adduced.

There was no consistency in the ash contents of the dried products and could be due to the possible inconsistency in the bone removal of the dried products before milling for analysis. However, the ash contents of all the dried products showed appreciable levels to indicate the dried fish products as good sources of mineral contents.

Table 2 shows the sodium, magnesium, and calcium and potassium contents of differently salted *O. niloticus* using Enclosed Solar Drying Systems. Sodium differed significantly ($p<0.05$) in all the three solar dryers. The mean sodium content showed that all the unsalted dried products were very low in sodium. This was expected, as *O. niloticus* is generally low in sodium content (ILO-WEP, 1982). However, all other dried products showed high levels of sodium especially in the STD, and be due to the rate of diffusion of salt into and the ex-osmosis of water out of the fish tissues, which is proportional to the concentration gradient between the salting medium itself at the surface and at the point in the fish most remote from salting medium (Horner, 1994). However, this was not true for the other two drying methods of NACD and FACD.

The potassium content of the STD 75% brined treatment was highest compared to other dried products. Each of the dried products showed high levels of potassium. Dried products from the STD had mean magnesium and calcium contents that were best when compared to NACD and FACD. All the dried products had high levels of free fatty acid contents indicating that all the products were becoming rancid. Eyo (2001) stated that rancidity has occurred in a fish with over 1.5% free fatty acid content. However, the level of rancidity was more pronounced in FACD dry salted while STD 50 had the least rancidity.

The iodine number, an indicator of unsaturation, was low in all the dried products. The highest which was 19.05 was found in STD 50 (Table 3) which again confirmed that rancidity had set in. This level of rancidity portrayed that lipid oxidation had taken place and according to Alais and Linden (1999) lipid oxidation involves loss of vitamin activity and colour. Oxidation of essential fatty acids lowers their nutritional value in food.

Table 4 shows FFA, IN and TVC of differently salted open-air dried O. *niloticus*. The FFA IN and TVC differed

Table 2: Mean values of sodium, potassium, magnesium and calcium contents of *O. niloticus* differently salted and dried using Enclosed Drying Systems (EDS)

	Salt levels	Sodium mg Kg^{-1}	Potassium mg Kg^{-1}	Magnesium mg Kg^{-1}	Calcium mg Kg^{-1}
Std	Unsalted	783.13	3,600.72	2.02	859.16
	25% Brined	35,941.34	2,921.53	2.05	713.67
	50% Brined	36,273.70	2,481.23	1.99	730.33
	75% Brined	39,149.29	2,489.50	1.96	733.03
	Dry salted	46,863.07	3,689.85	1.98	803.20
Nacd	Unsalted	561.07	1,966.49	1.45	543.81
	25% Brined	21,809.73	2,027.45	1.48	579.01
	50% Brined	31,053.93	2,656.34	1.52	565.44
	75% Brined	28,842.57	2,898.63	1.47	568.25
	Dry salted	22,299.05	2,364.83	1.50	760.80
Facd	Unsalted	650.51	2,018.65	1.50	642.09
	25% Brined	33,238.38	2,611.47	1.48	737.50
	50% Brined	26,084.32	2,366.36	1.47	620.97
	75% Brined	22,500.41	2,880.52	1.48	620.69
	Dry salted	12,555.63	2,450.80	1.50	759.12

Table 3: The amino acid content of *O. niloticus* dried using enclosed solar drying systems

Enclosed drying systems	Amino acids g 100 g^{-1} protein: Lysine	Histidine	Arginine	Aspartic Acid	Threonine	Serine	Glutamic acid	Proline	Glycine	Alanine	Cystine	Valine	Methinine	Isoleucine	Leucine	Tyrosine	Phenyalanine
Solar Tent Dryer	6.93^{a}	3.34^{a}	9.02^{a}	9.84	4.02^{a}	4.89^{b}	14.14^{c}	4.94^{a}	4.91^{a}	5.83^{a}	0.96^{a}	4.83^{c}	2.45^{c}	5.71^{b}	5.81^{a}	3.21^{b}	4.67^{a}
	±0.07	±0.02	±0.01	±0.00	±0.02	±0.00	±0.01	±0.00	±0.01	±0.01	±0.00	±0.01	±0.01	±0.01	±0.01	±0.00	±0.01
Natural Airflow Cabinet Dryer	7.26^{b}	3.64^{b}	9.20^{b}	9.84^{b}	4.07^{b}	4.69^{a}	13.62^{a}	5.16^{b}	5.04^{c}	6.26^{b}	1.18^{b}	4.52^{b}	2.35^{a}	5.78^{a}	5.73^{b}	3.21^{b}	4.68^{a}
	±0.01	±0.01	±0.00	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.00	±0.01	±0.00	±0.00	±0.01	±0.00	±0.01	±0.01
Artificial Airflow Cabinet Dryer	7.27^{b}	3.59^{b}	9.19^{b}	9.79^{a}	4.12^{c}	4.70^{a}	13.85^{b}	5.32^{c}	5.01^{b}	6.30^{c}	0.97^{a}	4.50^{a}	2.41^{b}	5.85^{a}	5.73^{c}	3.03^{a}	4.77^{b}
	±0.00	±0.03	±0.01	±0.00	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.03	±0.01	0.00
	7.16	3.52	9.13	9.83	4.07	4.76	13.86	5.14	4.99	6.13	1.04	1.04	2.4	5.78	5.76	3.15	4.71
±SEM	±0.06	±0.05	±0.03	±0.01	±0.02	±0.03	±0.07	±0.06	±0.02	±0.08	±0.04	±0.04	±0.14	±0.02	±0.01	±0.03	±0.17

Values in the same row with similar superscripts are not significantly different from each other ($p>0.05$)

Table 4: Mean values of free fatty acid, iodine number and total viable count of *O. niloticus* differently salted and dried using Enclosed Drying Systems (EDS)

	Salt levels	Free fatty acid %	Iodine number	Total viable kount 10^{-6}
Std	Unsalted	55.07^{j}	11.98^{d}	62.46^{l}
	25% Brined	49.52^{h}	11.96^{d}	53.22^{k}
	50% Brined	15.15^{a}	19.05^{l}	84.18^{n}
	75% Brined	17.07^{c}	13.67^{f}	66.41^{m}
	Dry salted	44.64^{g}	16.68^{j}	39.12^{j}
Nacd	Unsalted	54.08^{i}	11.39^{c}	5.25c
	25% Brined	32.95^{e}	17.53^{k}	19.53^{h}
	50% Brined	20.94^{d}	15.81^{h}	30.97^{i}
	75% Brined	15.63^{c}	12.06^{d}	6.31^{d}
	Dry salted	43.69^{f}	13.93^{fg}	2.30^{a}
Facd	Unsalted	61.38^{m}	13.31^{e}	13.82^{f}
	25% Brined	80.32^{n}	16.19^{i}	6.28^{d}
	50% Brined	58.80^{l}	9.16^{a}	14.20^{g}
	75% Brined	57.85^{k}	10.90^{b}	11.03^{e}
	Dry salted	84.96^{o}	14.10^{g}	3.20^{b}

Data in the same column carrying the same superscript do not differ significantly from each other ($p>0.05$)

significantly ($p<0.05$) in each of STD, NACD and FACD. In all the treatments in the three solar dryers high values of FFA IN and TVC were observed. These high values were more pronounced in FACD. The total viable count did not show any particular trend in the different levels of salting in the three drying systems. However, the dried products from the STD showed high levels of microbial count with the highest coming from STD 50. Whereas the dried products from the cabinet dryers especially the FACD, showed low levels of microbial count. This was an indication that dried products from the STD were prone to microbial spoilage than the cabinet dryers.

The essential amino acids-arginine, lysine, valine, methionine, iso-leucine, leucine, threonine, tyrosine, tryptophan and phenylalanine (Table 3) showed comparable high levels to the studies of (Eyo, 2001). Also, it showed that dried products from the three enclosed drying systems showed that the available amino acid after drying were high when compared to the findings of Sadiku and Oladimeji (1989) on the amino acid profile of *Sarotherodon galilaeus*.

CONCLUSION

In conclusion, all the dried products salted at 25% brine gave the highest crude protein content in each of the drying methods. It could be concluded that to get the highest crude protein content using the three drying methods of STD, NACD and FACD in conjunction with salting, it is best to salt at 25% brine as this showed a level of consistency in the drying methods.

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